CLAIMS

We claim:

1. A microcombustor comprising:

    a first section comprising a combustion fuel channel having an inlet for connecting the microcombustor to a combustion fuel source and an outlet at a top surface of said first section; and

  a second section disposed next to the first section;

the second section comprising:

    a combustion chamber having an inlet in fluid communication with the outlet of the channel of the first section and an outlet capable of evacuating combustion exhaust products; and

    an exhaust channel having an inlet in fluid communication with the outlet of the combustion chamber and an outlet at a surface of said second section;

  wherein the combustion fuel channel and the exhaust channel are disposed on a same side with respect to the combustion chamber, so as to form a first heat exchanger.

2. The microcombustor of claim 1, wherein the combustion fuel channel and the exhaust channel are disposed in planes substantially parallel to each other.

3. The microcombustor of claim 2, wherein the combustion fuel channel and the exhaust channel are substantially parallel to each other.

4. The microcombustor of claim 1, wherein a first heat transfer layer is disposed between the first section and the second section.

5. The microcombustor of claim 4, wherein a second heat transfer layer is disposed on the second section.

6. The microcombustor of claim 1, wherein a combustor catalyst is disposed in the combustion chamber.

7. The microcombustor of claim 1, wherein a liquid evacuation system is disposed in the exhaust channel.

8. The microcombustor of claim 7, wherein the liquid evacuation system comprises a wick.

9. A fuel cell comprising the microcombustor of claim 1.

10. A microcombustor comprising:

a gas inlet connected to a reaction chamber;

a liquid feed system connected to the inlet of the reaction chamber;

a reaction chamber having an internal volume of 100 mm^3 or less;

an outlet connected to the reaction chamber; and

a liquid evacuation system disposed in at least one of said inlet and said outlet, the liquid evaporation system comprising a wick, packed tube or capillary tube.

11. A microcombustor according to claim 10, wherein the outlet has a length as least as long as its diameter.

12. A microcombustor according to claim 10, wherein the outlet has a diameter that is no more than two times larger than the largest internal diameter of the reaction chamber; and at least one of the liquid feed system and the liquid evacuation system comprises a wick.

13. A microcombustor according to claim 10, wherein wherein the outlet has a diameter that is no more than two times larger than the largest internal diameter of the reaction

chamber; and at least one of the liquid feed system and the liquid evacuation system comprises a packed tube.

14. A microcombustor according to claim 10, wherein wherein the outlet has a diameter that is no more than two times larger than the largest internal diameter of the reaction chamber; and at least one of the liquid feed system and the liquid evacuation system comprises a capillary tube.

15. A fuel cell comprising the microcombustor of claim 10.

16. A steam reformer, comprising

a microcombustor as defined in claim 1; and

a third section comprising a reformation channel having an inlet for supplying reformation fuel and an outlet for evacuating reformation products,

wherein the exhaust channel and at least a portion of the reformation channel are disposed on a same side with respect to the combustion chamber, so as to form a second heat exchanger.

17. The steam reformer of claim 16, wherein the exhaust channel and the reformation channel are disposed in planes substantially parallel to each other.

18. The steam reformer of claim 17, wherein the exhaust channel and the reformation channel are substantially parallel to each other.

19. The steam reformer of claim 16, wherein a second heat transfer layer is disposed between the second and third layers.

20. The steam reformer of claim 16, wherein a reformation catalyst is disposed in the reformation channel.

21. The steam reformer of claim 16, wherein a liquid evacuation system is disposed in the exhaust channel.

22. The steam reformer of claim 21, wherein the liquid evacuation system comprises a wick.

23. A fuel cell comprising the steam reformer of claim 16.

24. A steam reformer, comprising:

a combustion chamber having an inlet and an outlet, a combustion catalyst being disposed in the combustion chamber; and

a reformation chamber having an inlet and an outlet, a reformation catalyst being disposed in the reformation chamber,

wherein the combustion catalyst and the reformation catalyst are disposed on opposite faces of a separation plate disposed between the combustion chamber and the reformation chamber; and

wherein the combustion chamber has a volume of 0.05 ml or less.

25. The steam reformer of claim 24, wherein at least one of the combustion catalyst and the reformation catalyst forms a coat on the separation plate.

26. The steam reformer of claim 24, wherein the inlet and outlet of the combustion chamber are in fluid communication with channels disposed on a side of the combustion chamber opposite the separation plate, and the inlet and outlet of the reformation chamber are in fluid communication with channels disposed on a side of the reformation chamber opposite the separation plate.

27. The steam reformer of claim 26, wherein the respective inlets are disposed in respective central portions of the faces of the respective chambers, and the respective outlets are disposed in respective peripheral portions of the respective chambers.

28. The steam reformer of claim 24, wherein a preheating chamber in fluid communication with the outlet of the combustion chamber is disposed on a side of the combustion chamber opposite the separation plate.

29. The steam reformer of claim 28, wherein the preheating chamber is an annular chamber surrounding an elongated channel in fluid communication with the inlet of the combustion chamber.

30. The steam reformer of claim 24, wherein a liquid evacuation system is disposed in the exhaust channel.

31. The steam reformer of claim 30, wherein the liquid evacuation system comprises a wick.

32. A fuel cell comprising the steam reformer of claim 31.

33. A steam reformer, comprising

a combustion chamber having an inlet and an outlet, a combustion catalyst being disposed in the combustion chamber; and

a reformation chamber having an inlet and an outlet, a reformation catalyst being disposed in the reformation chamber,

the combustion chamber and the reformation chamber being disposed around an axis,

the inlet and outlet of the combustion chamber being in fluid communication with combustion fuel and combustion exhaust channels, respectively, and the inlet and outlet of the reformation chamber being in fluid communication with reformation fuel and reformation products channels, respectively,

wherein the combustion fuel channel is disposed along the axis on a side of the combustion chamber opposite the reformation chamber,

wherein the reformation fuel channel is disposed along the axis on a side of the reformation chamber opposite the combustion chamber,

wherein the reformation products channel is disposed outside the reformation fuel channel with respect to the axis and on the side of the reformation chamber opposite the combustion chamber, and

wherein the combustion exhaust channel is disposed outside the reformation fuel channel with respect to the axis and on the side of the reformation chamber opposite the combustion chamber.

34. The steam reformer of claim 33, wherein the combustion exhaust channel is disposed outside the reformation products channel with respect to the axis.

35. The steam reformer of claim 34, wherein the reformation products channel and the combustion exhaust channel are substantially annular channels.

36. The steam reformer of claim 33, wherein a preheating chamber in fluid communication with the outlet of the combustion chamber is disposed on the side of the combustion chamber opposite the reformation chamber.

37. The steam reformer of claim 36, wherein a heat transfer plate is disposed between the combustion chamber and the preheating chamber.

38. The steam reformer of claim 36, wherein the preheating chamber comprises an annular chamber surrounding the combustion fuel channel.

39. A fuel cell comprising the steam reformer of claim 33.

40. A steam reformer, comprising:

a combustion chamber having an inlet and an outlet; and

a reforming chamber having an inlet and an outlet,

wherein the outlet of the combustion chamber surrounds the outlet of the reforming chamber, and wherein the outlet of the reforming chamber surrounds the inlet of the reforming chamber.

41. A fuel cell comprising the steam reformer of claim 40.

42. A steam reformer, comprising:

a combustion channel comprising a combustion chamber having an inlet and an outlet; and

a reforming channel comprising a reforming chamber having an inlet and an outlet,

the reforming chamber comprising two end sides and a peripheral lateral side, wherein the combustion channel surrounds the reforming chamber over at least one of the end sides and the peripheral lateral side.

43. A fuel cell comprising the steam reformer of claim 42.

44. A steam reformer comprising:

a first inlet connected to a first reaction chamber;

a second inlet connected to a second reaction chamber;

a heat transfer plate comprising first and second major surfaces,

the first major surface being in thermal contact with the first reaction chamber,

the second major surface being in thermal contact with the second reaction chamber,

wherein the first reaction chamber comprises a combustion catalyst or a steam reforming catalyst,

wherein, if the first reaction chamber comprises a combustion catalyst, the second reaction chamber comprises a steam reforming catalyst; or if the first reaction chamber comprises a steam reforming catalyst, the second reaction chamber

comprises a combustion catalyst, and

wherein the first inlet is connected to the first reaction chamber such that, during operation, fluid flows in more than one direction through the first reaction chamber.

45. A fuel cell comprising the steam reformer of claim 44.

46. A method of steam reforming comprising passing a fluid through the steam reformer of claim 44.

47. The method according to claim 46, wherein the fluid is a mixture comprising water and hydrocarbon.

48. A steam reformer comprising:

a first reaction chamber connected to a first inlet and a first outlet;

a second reaction chamber connected to a second inlet and a second outlet;

the first reaction chamber and the second reaction chamber being in thermal communication,

wherein the first reaction chamber comprises a combustion catalyst or a steam reforming catalyst,

wherein, if the first reaction chamber comprises a combustion catalyst, the second reaction chamber comprises a steam reforming catalyst; or if the first reaction chamber comprises a steam reforming catalyst, the second reaction chamber comprises a combustion catalyst, and

wherein the first inlet and the first outlet are connected to the first reaction chamber such that, during operation, fluid flows in more than one direction through the first reaction chamber between the first inlet and the first outlet.

49. A fuel cell comprising the steam reformer of claim 48.

50. A method of steam reforming comprising passing a fluid through the steam reformer of claim 49.

51. The method according to claim 50, wherein the fluid comprises water and hydrocarbon.

52. A microcombustion process comprising:

providing a composition comprising combustion fuel and oxidant to a combustion chamber, and

passing the composition through a combustion catalyst,

wherein the combustion catalyst comprises a porous matrix arranged such that sufficient mixture flows through the catalyst to maintain a combustion at a temperature of at most about 500°C;

reacting the composition in the combustion chamber to produce heat;
wherein the step of reacting fuel with oxidant produces heat and said heat is sufficient to sustain the microcombustion process without energy input.

53. A microcombustion process according to claim 52, comprising preheating the mixture prior to its entry into the combustion chamber, so as to maintain combustion at a temperature of at most 500°C.

54. A microcombustion process according to claim 53, comprising transferring heat from exhaust gases to the combustion fuel/oxidant mixture prior to its entry into the combustion chamber.

55. A steam reforming process, comprising:

passing a reformation gas through a reforming chamber,

maintaining combustion of a combustion fuel in a combustion chamber, so as to transfer heat from the combustion chamber to the

reforming chamber,

wherein a temperature difference between the combustion chamber and the reforming chamber is at most about 100°C.

56. A steam reforming process according to claim 55, comprising evacuating combustion exhaust gases from the combustion chamber so as to transfer heat from the combustion exhaust gases to the reforming chamber.

57. A method of making hydrogen gas, comprising:

passing a composition comprising H_2O and hydrocarbon into a reforming chamber and reacting said H_2O and hydrocarbon in said reforming chamber to form a hydrogen rich gas mixture;

passing a composition comprising fuel and oxidant into a combustion chamber and, simultaneous to the step of reacting H_2O and hydrocarbon, reacting said fuel and oxidant in said combustion chamber to produce heat;

wherein the reforming chamber and the combustion chamber are separated by a thermally conductive layer;

transferring heat from the combustion chamber to the reforming chamber;

wherein the average thermal transport distance from the combustion chamber to the reforming chamber is 1 mm or less;

wherein at least 80% of said fuel is oxidized in the combustion chamber; and

wherein the method comprises at least one of the following characteristics: (1) at least 80% of the fuel is oxidized in the combustion chamber and the thermal efficiency of the method is at least 5%; (2) hydrogen gas production of at least 30 sccm (standard cubic centimeters per minute) H_2 per cc of steam reformer volume; or (3) hydrogen gas production of at least 1 sccm H_2 per cc of device volume.

58. The method of claim 57 wherein the thermal efficiency is at least 7%.

59. The method of claim 57 wherein the thermal efficiency is 5 to 20%, and the hydrogen gas production is at least 1 sccm H_2 per cc of device volume.

60. The method of claim 57 wherein the thermal efficiency is 5 to 25%.

61. The method of claim 59 wherein the combustion reaction is performed at a temperature of at most about 425°C and the reforming reaction is performed at a temperature of at most about 325°C.

62. A method of steam reforming, comprising:

passing a reformation gas through a reforming chamber,

maintaining combustion of a combustion fuel in a combustion chamber, so as to transfer heat from the combustion chamber to the reforming chamber,

wherein the reforming chamber is configured such that the volume of the chamber increases as a function of distance from a reaction chamber inlet; and

expanding reformation gas and products as they pass through the reforming chamber.